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A Compleat

DISCOVERY

OF A

METHOD

Of Obſerving the

Longitude at SEA.

BY

GEORGE GORDON, Gent.

LONDON;

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March 25. 1724.

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DISCOVERY

OF A

NEW GOLD

OR

Imperial Mine

BY

GEORGE GORDON, CAPT.

LONDON:

A Compleat

DISCOVERY, &c.

IT is well known, that the Longitude may be found at Sea, if the Time of Day at the Place where, and at the Place from whence Longitude is computed, be given at the ſame Inſtant. There are Methods already known, by which the former of theſe *Data* may be had: I ſhall hereafter ſhow how theſe Methods may be very much improved; but it being univerſally underſtood that the Difficulty

culty which intirely hinders the Longitude to be found at Sea, does not lie there; I ſhall at preſent only ſpeak of the Method of finding the Time of Day at the Place from whence Longitude is computed.

IT is alſo well known, that by Obſervation of the Eclipſes of the *Satellites* of *Jupiter*, the Time of Day at the Place from whence Longitude is computed, may be known; and in Conſequence of that, it is found by Experience, that the Longitude at Land, where that Obſervation can be made, is actually found by that means. There are many other Aſtronomical Obſervations, by which the ſame End may be attain'd; to wit, The Tranſits of the *Satellites* of *Jupiter*, the Eclipſes and Tranſits of the *Satellites* of *Saturn*, the apparent Motion of the Spots that appear upon the Faces of the Planets, ariſing from their turning upon their Axes, *&c.* of all which I ſhall treat

in a little time, when I write more particularly upon this Subject: But as all these contribute only to enlarge the Number of Opportunities of finding the Longitude, and are not simply necessary for finding it, I shall at this time only speak of the Eclipses of the *Satellites* of *Jupiter*, being for some very good Reasons obliged to use all possible Brevity; and shall therefore at present take it for granted, that if the Observation of the Eclipses of the *Satellites* of *Jupiter* can be made practicable at Sea, the Longitude may also be found.

THE Reason why that Observation is not practicable at Sea, is this; It requires Telescopes that magnify much, and these cannot be managed on board a Ship; and in order to judge, whether what I am going to propose for taking away this Difficulty be sufficient for that purpose, it is necessary to understand first, what is the Nature of that

that Difficulty, that it may appear whether the Remedies propoſed for it, be of ſuch kind as ſuits it; and ſecondly, what is the Quantity of it, that it may appear whether the Remedies be adequate to it.

THE Nature of the Difficulty of managing at Sea Teleſcopes which magnify much, is this; they are long, and conſequently cumberſome, and their great Magnifying requires them to be accurately directed to an Object, in order to ſhow it, and accurately kept in that Direction, to keep the Object in view: and the Direction of the Inſtrument being varied as the Ship moves, this Accuracy is thereby prevented: The more the Inſtrument magnifies, the greater Accuracy being required, and the greater Accuracy that is required, the harder it is to manage it at Sea.

THE Reaſon why the more a Teleſcope magnifies, the more accurately

curately it must be directed to any certain Object for ſhewing it, is this: The apparent Space ſeen at one View, which I ſhall call the Area of Viſion, is not greater in Teleſcopes that magnify much, than in thoſe that magnify little; and therefore in great Magnifiers, a Space which is really ſmall, or rather which ſubtends a ſmall Angle at the Obſerver's Eye, fills up the whole Area of Viſion: And it being true, that any Teleſcope, in order to its ſhewing a certain Object, muſt not vary from being exactly directed to it by the Angle, which all the Space it ſhews at one View, really ſubtends at the Obſerver; it follows, that by how much the leſs this Angle or Space is, by ſo much the greater Accuracy, in directing the Inſtrument, is neceſſary. From whence it appears, that the Difficulty of managing Teleſcopes which magnify much, in as much as it ariſes not from their Length, but from their Magnifying, con-

ſiſts in this, that all the Space which makes up their Area of Viſion, or which they ſhew at one View, does really ſubtend but a ſmall Angle at the Obſerver.

THUS much for the Nature of the Difficulty, which hinders the Obſervations of the Eclipſes of the *Satellites* of *Jupiter* from being practicable at Sea; it remains to ſhew the Quantity of this Difficulty; for if Men be left to magnify or diminiſh in their own Mind its Quantity, they may be apt to err in eſtimating it, or, perhaps, rather only form an indefinite Idea of it, and conſequently not be able to give any certain Judgment at all in the Matter; ſince that can only be founded upon a belief, that the Quantity of the Remedy is ſuitable or unſuitable to the Quantity of the Difficulty that is to be remedied.

THERE may be a great deal ſaid, to ſhow that the managing of

Inſtruments of any kind does not prove near ſo hard, after a little Practice, as it appears at firſt; and this is ſo far true, that Men would be apt to conclude almoſt all ſorts of Workmanſhip impracticable, if the contrary did not appear, becauſe the Management of the Tools, by which they are made, ſeems to thoſe, who are unaccuſtomed to them, ſo very hard. But I ſhall not at preſent enlarge upon this Matter, and only draw from it this Conſequence, which will undoubtedly be granted, That the Queſtion how far any Inſtrument is manageable, ought to be determined, by enquiring how far it is found by the Experience of thoſe who have tried it to be ſo, rather than by the Opinions which People who have not tried it may form of the Eaſe or Difficulty of managing it. And it does appear from the Experience of thoſe who have tried it, that a little Practice will enable a Man to make Aſtronomical

Obſervations at Sea with a Teleſcope of five or ſix Foot long in moderate Weather, at which time only ſuch Obſervations are to be expected even at Land. For the Truth of which, we have the Teſtimony and Authority of that famous and learned Aſtronomer Dr. *Halley*, who tells us, in the Appendix to his Edition of *Aſtronomiæ Carolina*, that he found this by Experience. Nay, this great Man not only teſtified this, but, in conſequence of the Truth of it, applied himſelf wholly for almoſt three Years to Aſtronomical Obſervations, which would have been uſeleſs for the Purpoſe for which he deſigned them, if in that he had been miſtaken, as will appear to any Perſon who thinks fit to examine that Appendix. I ſhall therefore, without ſaying any more upon this Head, take it for granted, that a common Teleſcope of five or ſix Foot can be managed on board a Ship; and it is well known, that a Teleſcope of twenty

twenty Foot, or rather leſs, is ſufficient for obſerving the Eclipſes of the *Satellites* of *Jupiter*. Now theſe Inſtruments differ in nothing but in their Length and Magnifying, and conſequently it muſt ariſe either from its Difference of Length or Magnifying, or both, that a Teleſcope of twenty Foot cannot be managed at Sea, ſince one of ſix Foot can. The Difference of the Length of theſe Inſtruments is evident, and the Magnifying of common refracting Teleſcopes being univerſally as the Square Roots of their Lengths, the Difference of their Magnifying is alſo evidently as two to one. It remains then for me to find means to remove fourteen or fifteen twentieth Parts of any Difficulty of managing a Teleſcope of twenty Foot at Sea, that can ariſe from its Length, and one half of any Difficulty that can ariſe from its Magnifying, in order to make it as manageable at Sea as one of ſix Foot.

AS for the Length, it is ſufficient to ſay, that I am ready to ſhow a Reflecting Teleſcope of five or ſix Foot, whoſe Specula are of GLASS, equivalent to a Teleſcope of the common ſort of twenty Foot, and ſufficient for the Obſervation of the Eclipſes of *Jupiter*'s *Satellites*; and as to the Magnifying, I acknowledge it is proper this Inſtrument be made to magnify, as much as one of the common ſort of twenty Foot. For the more convenient Performance of this Obſervation, and for removing one half of the Difficulty ariſing from that Magnification, I propoſe the following Means.

COMMON Teleſcopes by reaſon of the Refraction of their Object Glaſſes, ſhow Things near the Limits of their Area of Viſion colour'd and indiſtinct, if an Eye-Glaſs be uſed, which is too great a Segment of a Sphere; or which is

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the ſame, if the Area of Viſion be made too big: This is what limits Workmen in the Quantity of the Area of Viſion which they make Teleſcopes to ſhow; and common Teleſcopes are ſcarce ever made to ſhow an Area of Viſion of above 25 Degrees, as will appear to any Perſon who pleaſes to examine that matter. It is to no purpoſe here, to ſay that theſe Inſtruments may be ſo contrived as to ſhow a greater Area; for though that be very true, it is not to the preſent Purpoſe, ſince the Queſtion is not what they might be made to do, but what they are in fact made to do.

SINCE Reflecting Teleſcopes gather not the Light by Refraction, they ſhow not Objects coloured, neither do they ſhew them indiſtinct towards the Limits of the Area of Viſion, 'till the Errors of the ſpherical Figure of the Eye-Glaſs occaſion Indiſtinction, which hinders not but that thoſe Inſtruments

ments can ſhow an Area of Viſion of above 60 Degrees, as will appear to thoſe who are pleaſed to look upon mine. Now it is evident, that if this Inſtrument ſhow an Area of Viſion of 60 Degrees, and magnify twice as much as a common five or ſix Foot Teleſcope, which ſhows an Area of Viſion of 25 Degrees; the former muſt have leſs of the Difficulties that ariſe from magnifying, than the latter, though it magnify more, becauſe it ſhows at one View more real Space; ſince, as I ſhowed before, thoſe Inſtruments which magnify much, are not for that Reaſon leſs manageable than thoſe which magnify leſs, but in as much as the former ſhow at one View, leſs real Space than the latter. And if any Man pleaſes to compare an Inſtrument of mine with a common five or ſix Foot Teleſcope, he ſhall find by trial, that though my Inſtrument magnify twice as much as the other, and be capable of ſhowing the Eclipſes of

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the *Satellites* of *Jupiter*, it is full as eaſy to find or keep an Object when found in it, as in the other; and that any Motion of the Inſtrument is not a greater Hindrance to the obſerving with the former, than with the latter, I mean, he will find it ſo, when all thoſe Aſſiſtances which I am going to propoſe, are laid aſide, and this one Advantage of the Greatneſs of the Area of Viſion only made uſe of; and yet this Advantage, compared with thoſe others which I am going to propoſe, is ſcarce worth regarding.

FOR, in the next Place, a Teleſcope of like magnifying with one of twenty Foot, or indeed of any Degree of magnifying, may be made to take in any given Quantity of real Space at one View. I know this will appear impoſſible to thoſe who are acquainted with theſe matters, and they may, perhaps, thus object, If an Inſtrument that magnifies as much as a common

Telescope of 20 Foot, can be made to take in at one View any real Space, let it take in eight times so much as a common six Foot Telescope, which shows an Area of Vision of twenty five Degrees, it being *ex Hypothesi*, of double magnifying; the real Space showed by the six Foot Telescope, will take up fifty Degrees of its Area of Vision; and consequently eight times so much will take up four hundred Degrees of that Area: But this is more Degrees than not only a Hemisphere, but even a whole Sphere contains: notwithstanding of this seeming Impossibility, the Thing propoled may be done in this manner.

IT is plain, that a Telescope by being made to magnify little enough, or, if any Man be captious, by being made to ~~magnify~~, can be made to take in at one View any given real Space; take then a Telescope showing at one View the real Space required, which I shall call the Index,

dex, and join it to another Teleſcope which magnifies as much as is deſired, in ſuch manner that a Man may look with his two Eyes into the two Teleſcopes at once, and ſo as that that Point of a diſtant Object which appears to be in the Center of the Area of Viſion of the Index, appear alſo to be in the Center of the Area of Viſion in the Teleſcope; thus the Obſerver ſhall not ſee two Areas of Viſion, but one Area only, the Sight of the one Eye not interfering with the Sight of the other Eye, more than it does when no Inſtrument is us'd. Let there be placed in that part of the Tube of the Index, where the Focus is formed, a circular Piece of ſome opake Subſtance, concentrick to the Area of Viſion, and of ſuch bigneſs, that being ſeen through the one Glaſs, it ſhall bear the ſame Ratio to the Area of Viſion of the Teleſcope, as the magnifying of the Index does to the magnifying of the Teleſcope: thus no Object

that is ſeen in the Index ſhall be ſeen in the Teleſcope, nor any Object that is ſeen in the Teleſcope be ſeen in the Index, but as an Object enters the Teleſcope, it goes out of the Index, to wit, is hid by the opake Circle, and as it goes out of the Teleſcope, it comes into the Index, that is, ceaſes to be cover'd by the opake Circle. And when the Obſerver wants to find an Object, for Inſtance, *Jupiter*, in the Teleſcope, the Index may be made ſuch as readily to ſhow that Object; and if ſo, the Obſerver has no more to do but to lead the Object ſeen in the Index toward the opake Circle, where when it comes, he will ſee it in the Teleſcope; or if the Motion of the Ship ſhould make it run out of his View in the Teleſcope, ſince it will ſtill be ſeen in the Index, he can bring it back to the Teleſcope, almoſt as eaſily, as a Man on Board a Ship, who is looking at any thing with his unaſſiſted Eye, can turn his Eye-ball, ſo as to ſee

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the Object ſtill in the middle of his View; for a very ſmall Motion of the Hand will do the former, as a very ſmall Motion of the Eye-ball does the latter: and it is plain from Experience, for inſtance of Muſicians who play upon the Violin, and ſeveral other Inſtruments, that ſmall Motions of the Hand and Fingers, do, by Habit, become as quick and ready as even the Motion of the Eye-ball itſelf; and it is only very ſmall Motions of the Hand, that can in this Caſe be neceſſary, of which Motions, the Object ſeen in the Index, will readily enough point out the Quantity and Direction, and Habit will as readily produce the Performance. The Contrivance of this Inſtrument, is very like that of the natural Eye; for as with it we ſee a great Space at once, but can only make minute Obſervations upon Objects when very near the Middle of it, the reſt of our View ſerving only to aſſiſt us, to bring any thing which we want to obſerve,

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into the middle of it; so in this Instrument it is only when an Object comes near the Center of the Area of Vision of the Index, that is, when it is in the Telescope, that it can be viewed minutely: all the rest of the Area of Vision of the Index serving only to enable the Observer to bring the Object readily to the middle. If Animals saw no greater Space at once than what they can see distinctly, they would be at the very same Loss in finding out and retaining things which it concerned them to see, especially in an unsteady Place, as the Users of Telescopes now are; and those who make use of Telescopes will, by this Assistance which I have now proposed, be in as much better Condition in that respect than they are at present, as Animals are in a better Condition than they would be, if they saw no more at once than what they can see distinctly.

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IT is needleſs to ſay any more at preſent upon this Head, but to deſire that People will come and look on it, and they will by that means underſtand this to be a greater Aſſiſtance than it is to be ſuppoſed Words can poſſibly perſuade them to believe: ſuch an Aſſiſtance as intirely takes off the Difficulty which hinders not only ſuch Magnifiers, as the Obſervation of the Eclipſes of *Jupiter*'s *Satellites* require, but any Teleſcopes whatever that are not too long, from being manageable at Sea. And this is ſo far true, that it is almoſt needleſs to propoſe any more Remedies for thoſe Difficulties which hinder Teleſcope Obſervations at Sea; though I ſhall yet propoſe very great Aſſiſtances, which may be added to what has been ſaid.

WHAT I have hitherto propoſed, ſerves for providing an Obſerver with Inſtruments, from uſing

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of which, the Disturbance he may meet with from the Motion of the Ship, cannot hinder him: yet I shall next show how that Disturbance may also be almost intirely avoided.

LET something sufficient to contain the Observer and his Instruments be hung; I shall not at present stay to describe what I conceive to be the best Method of hanging: but supposing a Place for the Observer to be hung commodiously, it will continue so as a Line drawn through its Center of Gravity, and the Point of Suspension be perpendicular to the Horizon, except in as much as it vibrates. These Vibrations may also be diminished in any Degree that can be desired, by placing the Observer as near the Center of the Ship's Motion as conveniently may be, and they may be made to be perform'd as slow as is needful, by adjusting the Length of the Pendulum; and though some small Vibration should con-

continue, it can cauſe but a ſlow and regular Motion of the Object; which when an Obſerver is once acquainted with, he may eaſily ſo compenſate with the Motion of his Hand, as not at all to be diſturbed by it. But beſide this Vibration, there is another Motion, and but another, by which the Direction of the Obſerver's Inſtrument can poſſibly be changed by the Motion of the Ship, and conſequently be diſturbed in his Obſervation: for ſuppoſing the Line drawn through the Center of Gravity of the Thing hung, and Point of Suſpenſion to continue perpendicular to the Horizon, that is to ſay, abſtracting from Vibration, there are no Directions into which the Motion of the Obſerver's Place can poſſibly put his Inſtrument, but to the ſeveral Points of ſome one certain Circle, whoſe Plan is parallel to the Plan of the Horizon; neither can the Direction of the Inſtrument be changed from any one Point of this

Circle, to any other, by the Motion of the Obſerver's Place, except in as much as it turns upon the Line drawn through its Center, and the Point of Suſpenſion as an Axis; nor can it turn upon this Axis, but in as much as the Direction of the Ship's Courſe varies, and conſequently this may be prevented by turning the Ship directly before the Wind, and letting the Helm go looſe, which will not be a great Hindrance to the Voyage, ſince the Time of Obſervation may be very nearly known. And leſt any Man ſhould here miſtake me, I deſire it to be conſidered, that when a Ship ſails upon a Wind, ſhe is by the beating of Wind and Waves made often to turn her Stem, but by means of the Helm returns quickly to her former Direction, and deſcribes a Line, which, if it be taken in general, is perhaps ſtreight; but if the minute Parts of it be ſeparately conſider'd, it conſiſts of a great many very ſhort Lines differ-

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ing far in their Directions; but theſe ſmall Irregularities neither affect the Compaſs ſenſibly, by reaſon of the quickneſs of their Returns, nor are they any ways to the Mariners Purpoſe to think of: for if the Ship deſcribe ſuch a Line as in its general Figure is ſtraight, though conſiſting of ſmall Lines of different Directions, it is to all Intents and Purpoſes of his, a ſtraight-lined Courſe; and yet theſe ſmall and ſudden Variations would prove extreamly hurtful to an Obſerver, by occaſioning a ſudden ſtarting away of his Object. On the contrary, a Ship before the Wind deſcribes by her Courſe a Line, which if conſider'd in its general Figure, is perhaps a Curve, but has no ſuch minute Irregularities as the former. Now this way of varying from a ſtraight Courſe, is what the Mariners are ſenſible of, from the Compaſs, and what does alſo concern them. But to an Obſerver, it will only occaſion a very ſlow and uni-

form, apparent, progreſſive Motion in the Object, or ſuch as perhaps may be altogether Imperceptible to him, and which he will as little regard, as the Mariners do thoſe ſmall Variations of the Ship's Courſe, which would give him ſo much Diſturbance.

IF any Man think fit to object againſt the Means which I have propos'd for making the Obſervation of the Eclipſes of the *Satellites* of *Jupiter* practicable at Sea, he muſt remember that it is not to the Purpoſe to make ſome Objection, or find ſome Fault with ſomething that I have ſaid; but his Objection muſt conclude all theſe Means inſufficient for the Purpoſe of making that Obſervation practicable at Sea, or elſe it ſignifies nothing; I deſire ſuch a Perſon alſo to remember, that what I have here ſaid, is only with the utmoſt Brevity to propoſe the Heads, and deliver the Subſtance of what I have to ſay, and that I

have neither largely explained and enforced it, nor endeavoured to obviate Objections; and if he ſhould think me as ill provided for anſwering Objections, as poſſibly I may, from that way of writing, appear to him, he may, perhaps, find himſelf miſtaken. The Reaſon why I am ſo ſhort, is this, I am preparing a full Account of this Matter in *Latin*, to be publiſhed in *France* and *Holland*, at the ſame time it is publiſh'd here; and ſince I did not find that I could manage a Publication of that kind, with ſuch ſecrecy and expedition as I conceived this Subject to require, I thought fit firſt to publiſh in this manner, that of whatever value this Method might happen to be, it might not, by any accident, become doubtful whoſe it was; I deſign'd alſo to publiſh in this manner, that I might thereby underſtand, before my general Publication, whether I ſhould meet with ſuch ſort of Oppoſition in this Affair as I have hitherto done, that I might

might neither neglect that opportunity of doing myſelf Juſtice in caſe I do, nor ſay a great deal that might, perhaps, be better ſpar'd if no ſuch Oppoſition be deſign'd. I wiſh that whoever may think of oppoſing me, would coolly think how he will find means to influence the Learned Men all over the World, to agree in ſaying, That a Thing is not ſo much as probable, for which there is ſuch Superabundance of Evidence; and it may not, perhaps, be amiſs alſo to inſinuate, that though this could poſſibly be effected yet in a ſhorter Time than is perhaps expected, I ſhall ſo change the State of the Queſtion, that the Determination of it may depend upon judging of the Credit of Witneſſes, rather than weighing the Strength of Arguments; and in that caſe, Learning will not be ſo much wanted for deciding it. In fine, I do promiſe that whatever part any Man chuſes to act, with reſpect to me, in this Affair, I ſhall exert myſelf to the

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utmoſt of my Power, in making him a ſuitable Return.

THIS Method, all but the particular Deſcription of the Inſtrument which I had not then made, I propoſed to the Commiſſioners appointed by Act of Parliament for encouraging the Diſcovery of the Longitude at Sea, the 16th of *December*, 1719. I ſhall neither complain that I had no Aſſiſtance from them, nor endeavour to ſhow, at this time, by whoſe Fault it was ſo; but only ſay, that I hope and expect that they will now act in this Affair, as their Duty to their Country, which has intruſted them with this Matter, requires at their hand.

I SHALL, with all poſſible ſpeed, provide a proper Place, and give publick Advertiſement of it, where Attendance ſhall be given to ſhow the Inſtruments; and, in the mean time, if any Perſon pleaſes to call or ſend for me at Mr. *Graeme*'s Houſe

House, the Green Door over against the three Pidgeons in *Barrow-bone Lane, Newgate-street*, I shall wait on him at what Place he pleases with the Instruments, and shew him them.